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Integration of FHIR to Facilitate Electronic Case Reporting: Results from a Pilot Study

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Abstract

Current approaches to gathering sexually transmitted infection (STI) case information for surveillance efforts are inefficient and lead to underreporting of disease burden. Electronic health information systems offer an opportunity to improve how STI case information can be gathered and reported to public health authorities. To test the feasibility of a standards-based application designed to automate STI case information collection and reporting, we conducted a pilot study where electronic laboratory messages triggered a FHIR-based application to query a patient's electronic health record for details needed for an electronic case report (eCR). Out of 214 cases observed during a one week period, 181 (84.6%) could be successfully confirmed automatically using the FHIR-based application. Data quality and information representation challenges were identified that will require collaborative efforts to improve the structure of electronic clinical messages as well as the robustness of the FHIR application.

Keywords:

Health Information Exchange, Disease Notification, Sexually Transmitted Diseases

Introduction

Sexually Transmitted Infections (STIs)

Undiagnosed and untreated sexually transmitted infection (STI) is associated with adverse outcomes such as infertility, increased HIV transmission and acquisition, and adverse pregnancy outcomes. Several STI health services are recommended by the U.S. Centers for Disease Control and Prevention (CDC) to protect the reproductive and sexual health of young men and women, including annual chlamydia and gonorrhea screening of sexually active women ≤ 24 years of age, pregnant women, and older at-risk women; chlamydia and gonorrhea screening of anatomic sites of exposure (urethral, rectal, or pharyngeal) of men who have sex with men (MSM); retesting of all infected persons after treatment for chlamydia or gonorrhea; and syphilis testing of pregnant women as well as sexually active MSM [6].

Surveillance of STIs and STI Services

Surveillance, a cornerstone of public health [23; 29], is the routine assessment of disease prevalence and burden as well as the utilization of health care services. Ministries of health seek to perform surveillance on a range of diseases including STIs. For example, most ministries seek to monitor the quality of STI health services received by at-risk groups such as adherence to recommendations for chlamydia and gonorrhea testing and retesting, syphilis testing, test results, patient and partner treatment, and the incidence of adverse STI outcomes.

Surveillance of STIs relies upon physicians and laboratories to manually, spontaneously report STI cases to public health authorities [2]. However, passive approaches are known to be burdensome for reporters, producing incomplete and delayed reports which can hinder the assessment of disease in the community and potentially delay the recognition of patterns and outbreaks [17; 20; 28]. For example, in a recent analysis of STI cases laboratories reported between 63.1% and 71.7%, and physicians reported between 6.3% and 44.4%, of syphilis, gonorrohea, and chlamydia cases [15].

Electronic Reporting of STIs

While most U.S. health agencies continue to publish offiical paper-based forms for STI case reporting [10; 16], surveillance practice is evolving towards electronic methods for data capture. The adoption of electronic health record (EHR) systems and health information exchange (HIE) among clinical organizations and systems [3; 4], driven by policies like the 'meaningful use' program in the United States [7], is creating an information infrastructure that public health organizations can leverage for improving surveillance practice [9].

To date, the focus of modernizing STI reporting has been on the implementation of electronic laboratory reporting (ELR). ELR messages utilize HL7 (Health Level 7) Version 2 standards to encode information about tests ordered and test results pertaining individual patients. The rapid adoption of ELR over the past decade now enables over two-thirds of health departments in the U.S. to improve the surveillance of STIs and other conditions [22]. Yet there are key data missing from ELR messages that public health agencies need to investigate STI cases. For example, at the time the lab result is electronically delivered to the physician, the ELR message does not contain the treatment to be prescribed by the physician. Therefore public health authorities need case information from providers beyond what is available in the initial ELR message.

To access complete information on STI cases, public health authorities seek to implement electronic case reporting (eCR) where case reports from providers are generated or submitted electronically. The goal is to leverage EHR systems and HIE networks to facilitate eCR. Although desired, there exist few standardized methods to support eCR within commercial EHR systems and few existing implementations of eCR.

Research Objective

Given the need for better community-level surveillance of STIs and limited experiences with eCR, we sought to develop and test a standards-based eCR service within the context of an existing HIE network. The goal was to establish the feasibility of such an approach to support public health work.

Methods

To examine whether eCR processes could be automated, we implemented and tested a standards-based application within an existing HIE network. The application received ELR messages indicating a positive lab result for chlamydia or gonorrhea and returned a completed eCR report with case information extracted from the patient's EHR. The completed eCR reports were stored in a local database to enable analysis for the study, but this repository could be used to transmit completed reports to a public health authority. Our work received approval from the Institutional Review Board (IRB) at Indiana University.

Geography and Population Information

The State of Indiana ranks 15th among U.S. states by population with just under 6.5 million residents, according to the 2010 census. Consistent with national data, minority race and ethnicity are over-represented in STIs. For example, the 2015 rate of gonorrhea among black (African-American) individuals was 836/100,000 people compared to the rate among whites (Caucasian) of 87.7 and for Hispanic individuals of 85.0. The rates for Chlamydia were 2234 for black, 319 for white, and 545 for Hispanic, and the rates for primary and secondary syphilis were 26.8, 6.6, and 16.6, respectively.

The Indiana State Department of Health (ISDH) STD Control Program divides the state's 92 counties into ten districts for morbidity reporting and disease intervention purposes. These district offices are the recipients of contracts with the STD Program for the state's approximately 30 disease intervention specialists. The Marion County Public Health Department (MCPHD) STD Control Program has responsibility for STD reporting in District 5, which includes Marion County (Indianapolis) and the seven surrounding counties: Boone, Hamilton, Hancock, Hendricks, Johnson, Morgan, and Shelby. This district makes up the majority of the Indianapolis MSA. District 5 (population of 1.7 million), and Marion County (population of 903,393) always account for the largest share of Indiana's STI morbidity. In 2015, District 5 accounted for 39% of the state's chlamydia and 47% of the state's gonorrhea morbidity. This reflects, in part, racial health disparities in the district which is substantially more diverse than the state.

According to the CDC's 2015 STD Surveillance Report, Indiana reported a total of 28,886 cases of Chlamydia and ranked 27th among states in rate (437.9/100,000) while Marion County ranked 25th among U.S. counties and independent cities at 949.3 cases/100,000 people. Indiana is ranked 23rd among states for gonorrhea with a case rate of 118.9/100,000 people, while Marion County is ranked 16th among U.S. counties and independent cities in the rate of gonorrhea cases with 344.1 cases/100,000 people.

Indiana Network for Patient Care

The Indiana Network for Patient Care (INPC) is one of the largest community-based HIE networks in the United States [24]. The INPC connects 117 hospitals representing 38 health systems with physician practices, long-term post-acute care facilities, laboratories, and radiology centers. The INPC maintains nearly six billion structured observations for over 12 million individuals. Nearly two million electronic health care transactions are processed every day.

Since 2000, the INPC has leveraged electronic laboratory messages sent from hospitals to automate the reporting of notifiable disease information to public health authorities. Using a technology dubbed the 'Notifiable Condition Detector' or 'NCD,' developed by the Regenstrief Institute, the INPC examines each incoming electronic lab message to determine if the results should be reported to public health authorities. In other words, the NCD is how the INPC facilitates ELR. In prior studies, the NCD was shown to have good sensitivity and specificity as well as improve the completeness and timeliness of public health reporting processes [11; 18]. This study leveraged the NCD to identify positive lab tests for chlamydia and gonorrhea sent during the study period. Specifically, the NCD identified tests from a value set defined in CDC case definitions and published by the Public Health Informatics Institute [26].

A FHIR-based Service for eCR

In partnership with the Georgia Tech Research Institute, the Regenstrief Institute implemented a FHIR-based application within the INPC. FHIR (Fast Healthcare Internet Resources) is an emerging HL7 standard that seeks to expose discrete health data through web services [19]. Using a FHIR-compliant server, organizations can expose health data as FHIR resources to external applications that can use requested resources to perform various functions. FHIR services have been integrated into existing EHR platforms like OpenMRS [21], i2b2 [25], and OMOP [1; 8].

For this study, the Regenstrief Institute installed a FHIR-based eCR application developed by Georgia Tech, entitled the Public Health Case Reporting (PHCR) platform. The application receives as input HL7-compliant ELR messages (Verion 2.5.1 Observation Result messages) from the NCD. These messages represent positive lab results for individuals tested for chlamydia and/or gonorrhea. The positive lab test messages trigger the PHCR application to query a previously-implemented FHIR-compliant server that exposes INPC data as resources for additional details about the disease case. The FHIR service running on top of the INPC provides the requested resources which are used by the PHCR application to populate an eCR along with the data from the original ELR message. These data are stored in a local database that permit the eCR to be submitted to a public health authority. Georgia Tech further developed a Web-based dashboard that enables the eCR data to be visualized from the database, which is useful for testing purposes as well as quality control. Source code for the project is available via GitHub in two distinct repositories: https://github.com/gt-health/ecr_manager and https://github.com/gt-health/PACER

The architecture implemented for the pilot study is depicted in **Figure 1**. The application developed by Georgia Tech is labeled as the PHCR Controller. The FHIR-based service that interacts with the INPC is labelled as the FHIR Controller. Messages from the NCD are fed into the PHCR Controller using a HL7 Version 2.5.1 Receiver. The Dashboard is a web application that displays eCR records stored in the local database connected to the PHCR Controller.

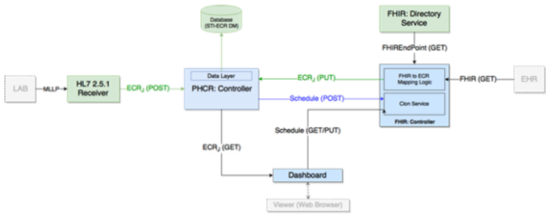

Figure 1– Architecture.

Once the FHIR-based service in the INPC returns a completed eCR, the report data are stored in a local database. Using a web application developed by Georgia Tech, the completed eCR reports can be viewed in a web browser. Figure 2 depicts part of a completed eCR report in a web browser for a test patient. The eCR contains details on the patient, guardian (if under 18 years of age), diagnosis, medications, and lab results. Also available are data on symptoms, health care facility, provider, clinic visits, travel history, and immunization history. These are the data elements important to disease investigators at public health authorities.

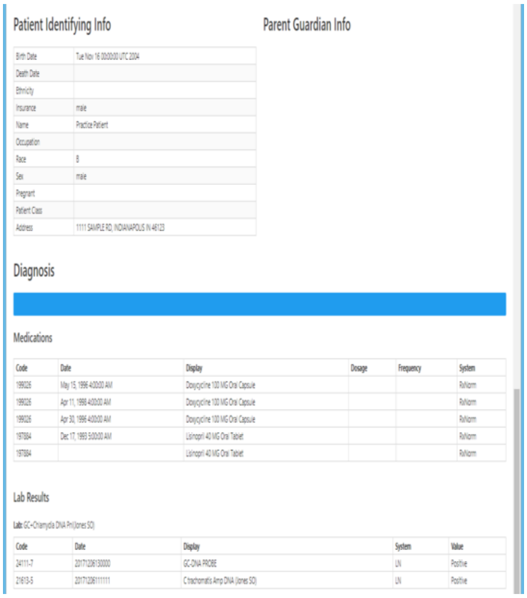

Figure 2 – Screenshot of electronic case report viewer application showing test patient information, including demographics, diagnosis, and laboratory results.

Data Collection and Analysis

Once implemented within the INPC, the FHIR-based eCR service was tested for one week (November 30, 2017 to December 6, 2018). Data were collected from the incoming ELR messages received by the INPC as well as the eCR reports generated by the FHIR-based service. Patient details, confirmatory lab test details, and corresponding ICD diagnoses from the eCR were collected to ensure that the correct linkages were made between initial ELR and final eCR for a given patient. Error logs were captured to identify issues with the service as well as potential mismatches between patients identified in the ELR messages and known patients in the INPC.

A descriptive analysis was performed to summarize the results of the pilot test. The throughput of the service was calculated along with general descriptions of the population with a positive STI observed during the pilot period. R (version 3.4.3) was used to calculate descriptive statistics and ggplot was used to create histograms and bar charts.

Results

A total of 214 ELR messages were received by the INPC from 16 health systems during the pilot test period. All (100%) ELRs were correctly matched to a patient's longitudinal medical record in the INPC via the FHIR service.

A date of disease onset was confirmed in the patient's medical record using ICD diagnosis codes for only 181 (84.6%) patients, enabling the FHIR service to return a completed eCR to the public health agency. Additional errors included:

- 5 (2.3%) ELR messages were missing test dates; and
- 4 (1.9%) ELR messages had phone numbers in an invalid format.

The distribution of patient age, stratified by gender, is depicted in Figure 3. Overall there were more females (N=157) diagnosed with an STI than males (N=57). However, the median age for both groups was similar (22 years for females and 23 years for males).

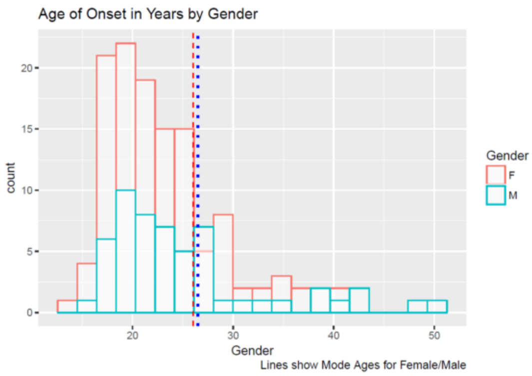

Figure 3 – Distribution of age by gender for those with a positive chlamydia or gonorrhea test.

The most prevalent laboratory test codes are summarized in **Table 1**. There were a total of 680 test results observed as several ELR messages contained multiple test results. Of the top seven lab tests observed, five were identified in the ELR message using the LOINC coding standard and two were identified using local lab codes (MIDAM is a regional lab located in Indianapolis, Indiana).

Table 1 – Prevalent laboratory test codes observed in electronic lab messages exchanged using the FHIR service.

Laboratory Test Code	Laboratory Test Code System	Laboratory Test Description	Count
21613-5	LOINC	*Chlamydia trachomatis* DNA	117
31208-2	LOINC	Specimen source identified	94
970000571	MIDAM	*Chlamydia trachomatis+ Neisseria gonorrhoeae* rRNA	93
4993-2	LOINC	*Chlamydia trachomatis* rRNA	89
5028-6	LOINC	*Neisseria gonorrhoeae* rRNA	89
10001637	MIDAM	*Chlamydia trachomatis* rRNA	52
24111-7	LOINC	*Neisseria gonorrhoeae* DNA	49

Discussion

In a pilot study to establish the feasibility of a standards-based approach to automate the collection of information in support of electronic case reporting for public health surveillance, we implemented a FHIR-based application that could query an HIE network for data necessary for eCR work processes. Real-world ELR messages for positive cases of chlamydia and gonorrhea were transmitted to the application over the course of one week. The application successfully queried the FHIR-based service at the HIE for 100% of lab positive results. For a high proportion (85%) of cases, the application could automate completion of the eCR for transmission to a public health authority. Therefore the pilot project established strong feasibility for automating eCR information flows, which has the potential to save time and cost for the health system as most eCR processes currently rely on clinical and public health personnel to call, fax, or manually enter information to and from organizations. Although feasible, we recognize that additional testing, refinement and study of FHIR-based approaches will be necessary to implement and scale eCR applications to automate information capture.

Although the pilot was considered successful, some errors challenged the application. ELR messages, the input that triggered the eCR process, were missing test dates in a small proportion (2.3%) of cases. In other cases (1.9%), the patient's phone number was improperly formatted. Data quality issues such as completeness and improper data representation are common in health care as documented in prior studies [12; 31]. Similarly, one quarter (25%) of the most common lab results were encoded using a local laboratory information system terminology as opposed to the internationally recognized standard LOINC. This challenge has also been observed in prior examinations of routine ELR messages sent to public health organizations [13]. These data quality and standardization challenges require work to make solutions like the PHCR application more reliable across the wide variation of ELR data feeds found in the health care system.

While a high proportion (85%) of cases were confirmed using EHR data returned from the INPC, several patient records were missing an ICD-based diagnosis that the eCR application requires to confirm a positive case of disease. Since each patient had a positive, confirmatory laboratory result for one of the two target diseases, these patients should have the respective disease documented in their EHR. The most likely reason why this diagnosis was missing from the EHR is clinic workflow as the lab result was reported to clinicians after the patient was no longer in the clinic or the emergency department and therefore clinic staff did not go into the EHR to update the record.

Tackling the data quality and standardization challenges will enable applications like the PHCR to better automate public health reporting processes. Health care organizations, information system vendors, and HIE networks can and should work to ensure that data are complete and properly represented in electronic messages using available health information standards. Solutions like terminology mapping exist to support efforts at improving data standardization [5]. Efforts also exist to support data quality improvements [14; 30].

Furthermore, applications like the PHCR need to be flexible and adapt to information feeds that may not perfectly provide all of the data necessary to trigger a case report for public health. This may require public health organizations to relax the rules for confirming a case, or application developers may need to configure software to enable eCR information moving forward even if the report is not complete. Thus we all have work to do in order to make applications like PHCR robust.

Currently the CDC, with support from the Robert Wood Johnson Foundation, is conducting a pilot program to test a 'digital bridge' between clinical and public health organizations for notifiable disease reporting in conjunction with the meaningful use program [27]. This project could provide a method for scaling automated eCR approaches beyond what we tested in this study. However, this project has not yet published early findings or preliminary results. More implementation and evaluation of these efforts will be required to achieve adoption rates as high as ELR. Furthermore, public health organizations should investigate policy drivers that may encourage eCR application adoption by health systems.

Conclusions

A pilot study to examine the implementation of a standards-based approach to support electronic case reporting for public health demonstrated feasibility. While successful, the pilot study identified errors and challenges that need to be addressed before a FHIR-based approach to electronic case reporting can be implemented and scaled across the health system. Technical and workflow improvements will be required to facilitate broad adoption of standards-based eCR in support of public health.

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